For Public Release

THEATER AIR AND MISSILE DEFENSE INTEGRATED DESKTOP ANALYSIS AND PLANNING SYSTEM

AIAA / BMDO Technology Readiness Conference

Authors: Gene Collinsworth / David Wollover / Michael VonPlinsky

Frontier Technology, Inc.
Falls Church, Virginia

THEATER AIR AND MISSILE DEFENSE INTEGRATED DESKTOP ANALYSIS AND PLANNING SYSTEM

Abstract

FTI's Integrated Desktop Analysis and Planning System (IDAPS) comparative assessment process and automated tool has been successfully used in a number of DoD studies to perform a structured evaluation a wide range of architectures / systems / technologies. The process embodies sound engineering principles to establish a framework that provides senior decision-makers with sufficient data to make informed decisions regarding the acquisition of systems, development of technology investment strategies, and the assessment of alternative architectures with both military utility and cost as principal measures in a "Cost as an Independent Variable (CAIV)" perspective. The IDAPS framework also supports establishing a permanent, readily accessible corporate knowledge base that preserves Intellectual capital through disciplined, structured and automated synthesis of information.

Introduction

The Theater Air and Missile Defense (TAMD) IDAPS Tool, one recent implementation of FTI's IDAPS capability, has been developed BMDO's TMD System Engineering Directorate (BMDO/AQE). This implementation was recently used to capture the results of the Theater Missile Defense (TMD) Cost and Operational Effectiveness Analysis (COEA) Study in support of the current TAMD Architecture Roadmap Study. The TAMD IDAPS Tool demonstrates how the assessment process and automated framework contributes to the comparative assessment, data manipulation, integration, visualization, and archival of the past TMD COEA results.

The TAMD IDAPS provides a comprehensive architecture assessment process in a COTS based, PC-Based environment. The process provides a complete forwards and backwards "Chain-of-Assessment" that remains traceable to the TMD CAPSTONE Requirements Document. The "Chain-of-Assessments" is based on a "Quality Function Deployment (QFD)" framework of linked matrices that reflect assessments of requirements, measures of effectiveness, system performance parameters, and raw analysis data. The framework also supports the integration of this data with risk and cost assessments. These assessments are dynamically rolled-up to the architecture level where a variety of flexible post processing features are provided, such automated CAIV profile development, key variable sensitivity analysis, and analysis results visualization.

A description of the challenges associated with managing a study such as the TMD COEA Study or the TAMD Acquisition Roadmap Study is presented in Section 1. The objectives of Integrated Desktop Analysis and Planning System are presented in Section 2. The major modules of TAMD IDAPS are presented in Section 3. Section 4 concludes this presentation with a summary the benefits provided by implementing FTI's IDAPS process and automated tools.

The Challenges – Study Scope and Complexity

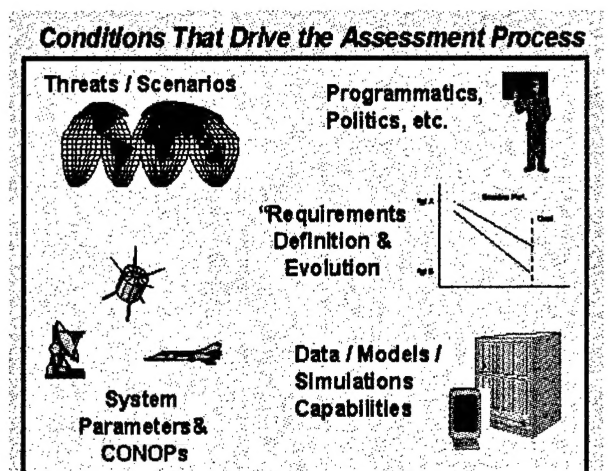

Figure 1 - Study Influences

The challenge that confronts studies such as the TAMD Acquisition Roadmap Study is managing the extensive and diverse scope of influences and complexity. Figure 1, Study Scope, identifies several conditions that drive the assessment process.

Threats/Scenarios – Theater Ballistic Missiles (TBMs) include systems with ranges of less than 5,500 km capability carrying Weapons of Mass Destruction warheads. TBMs are currently deployed around the world, including areas with the highest potential for conflict (the Middle East and Asia). As more nations begin deploying missile defenses, TBM developers will likely begin employing countermeasure techniques, which may not be expensive or involve high technology. This proliferation of TBM technology creates potential threat conditions that are numerous and complex.

Requirements Definition and Evolution – An increasingly complex analytical environment and growing magnitude of Joint influences on

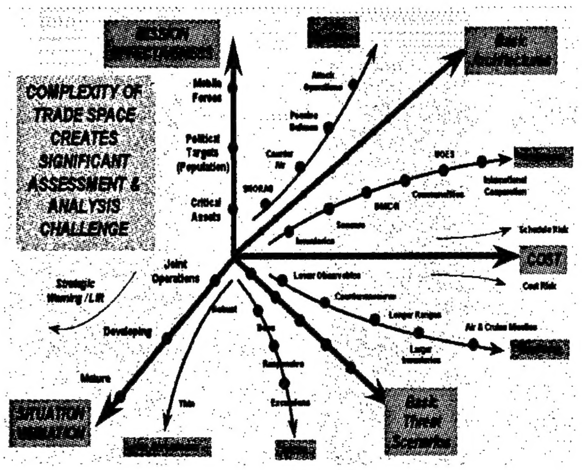

Figure 2 – Study Complexity

requirements characterize studies like the TAMD Acquisition Roadmap Study. Based upon shortcomings of existing systems to counter the postulated threat, requirements are identified in four operational areas: command, control, communications, computers, and intelligence, attack operations, active defense, passive defense. These requirements, however, are difficult to define and quantify, are difficult to prioritize, and the traceability back to requirements throughout the study is often lost or at best complex.

Data / Models / Simulations – In addition, threat scenarios and requirements, numerous models and simulations like EADSIM, CAPS and others are utilized to analyze systems and architectures. These models produce a variety of data types that ultimately require integration. Qualitative assessments that occur throughout the process add another layer of complexity to the data collection and assessment task.

The Trade Space – The scope and complexity of the Trade Space, portrayed in Figure 2, creates significant assessment and analysis challenges. A mechanism that integrates and manages performance analysis and assessment across a wide range of architectures, mission effectiveness, situation variations, threats and cost is required.

The complexity of the TAMD Study will increase as the study evolves. Note the evolutionary

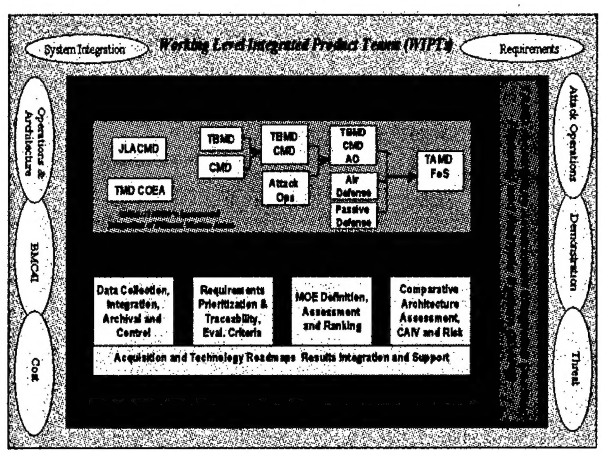

Figure 3 – The Assessment Process

process depicted in Figure 3. First TBMD and CMD are independently analyzed then integrated. These results are subsequently integrated over time with Attack Ops. The combined results are later integrated with Air Defense and Passive Defense.

There is also Multi-Agency Involvement. TAMD is inherently a joint mission and the architectures that result from this assessment must reflect the needs of the joint force commander. Outlying Figure 3 is eight Working Level Integrated Product Teams (WIPT) that support the Assessment process. Interdisciplinary team groups, such as WIPTs require ready access to an integrated knowledge base of current analytical influences as well as prior accumulated intellectual capital to benefit from other's experience.

The joint nature of the TAMD Study carries diverse reporting requirements, shown in Figure 4, which are comprehensive and traceable. It is difficult to establish and maintain the analytical connectivity needed to understand and analyze the dynamic relationships among requirements, measures of effectiveness, comparative architecture assessments, and the combined use of analytical results. All too often, references to requirements or decisions made during the assessment process are lost by the time architecture comparisons are executed.

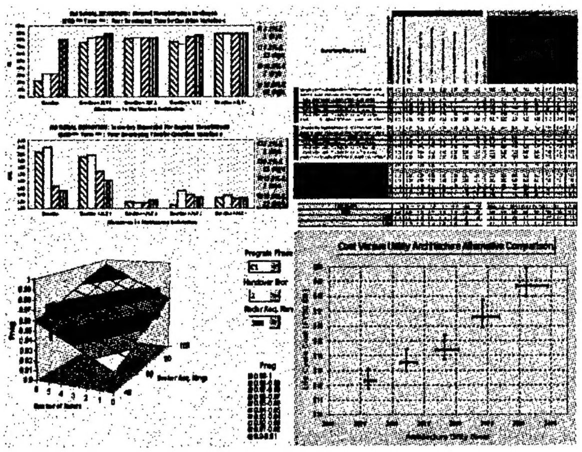

Figure 4 – Post Processing Requirements

Extensive and diverse "follow-up" to baselined comparative architectural assessments is difficult to coordinate for supporting integrated defensible acquisition roadmap conclusions.

Objectives of the IDAPS Process

FTI's IDAPS Process addresses the challenges of these studies through sound engineering principles that combine proved assessment methods, like the Analytical Hierarchy Process (AHP) and Quality Function Deployment (QFD), with data automation to create a framework to facilitate diverse assessments and the data integration and archival described above.

The framework is a comprehensive analytical environment for assimilating the growing complexity of analytical data. It provides the disciplined, structured; yet flexible methodology needed to assess the disparate parts of the architectures and integrate qualitative and quantitative analyses. The environment provides direct traceability to requirements and system performance parameters from anywhere in the assessment process. This traceability provides insights into how the combined influences of key architectural drivers effect the overall performance.

A primary feature of the IDAPS tool that sets it apart from other environments are the post processing modules, shown in Figure 5, that support "Quick-Turn" Sensitivity Analyses. In the TAMD IDAPS users could vary the priorities of requirements or measures of effectiveness and immediately see the impact to the overall architecture assessment. Additionally, the user could adjust other performance parameters like threshold or objectives. In each case the impact to the overall assessment was realized immediately. Furthermore, as changes were examined the "cases" could be saved for later comparison. These are but some of the examples where "Quick-Turn" Sensitivities have been utilized.

IDAPS provides a structure for inter- and intra-WIPT communication and data exchange. The tool is a commercial off the shelf (COTS) environment that that can easily be hosted to provide access across networks or the internet. IDAPS supports multi-level security, data warehousing and is totally user controlled.

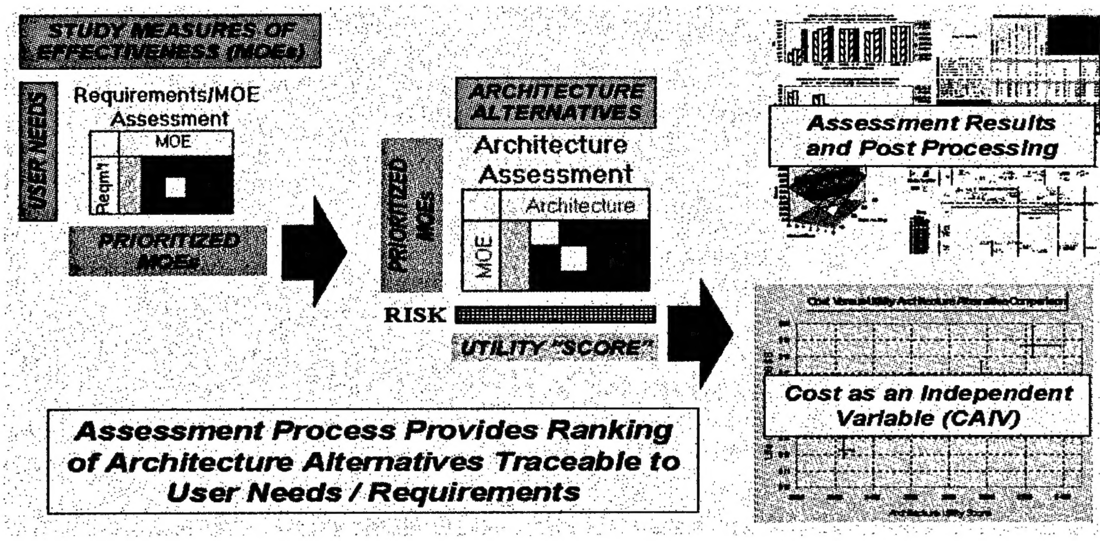

Figure 5 – Major "Modules" of TAMD IDAPS

Major Modules of TAMD IDAPS

Figure 5 presents the major modules of the TAMD IDAPS Process and Tool. These modules - the Requirements/MOE Assessment, the Architecture Assessment, and Assessment Results and Post Processing which includes the Cost as an Independent Variable (CAIV) profiles – are described below.

Requirements/MOE Assessment

The Requirement/MOE matrix, shown in Figure 6, presents the culminating results of the Requirements/MOE Assessment – a weighted set of MOE values that subsequently get forwarded for integration with the Architecture Assessment. But this is the conclusion. Let's first see where the process begins.

Requirements Assessments Process begins with the definition and prioritization. Typically the CAPSTONE Requirements Document (CRD) is a good starting place. Key Performance Parameters (KPP) typically define these requirements. Some definitions, however, are vague and required further clarification. In these cases, the requirements require refinement or clarified through the established requirement process.

The TMD COEA Study did not begin with requirements. After examination of the Capstone COEA for TMD TECHNICAL REPORT, 7/16/1996, the Summary of Phase I Findings for TMD CAPSTONE COEA, and Phase I Technical Briefing with Addendum, Final, 9/24/1996, the decision was made to utilize the OSD Issues as requirements for the Assessment. These documents identified ten OSD issues that were considered in this study. The framework supports these adjustments. A discussion of the OSD Issues was developed and is archived in the framework. OSD Issues represented requirements in this assessment to demonstrate the tool's flexibility.

The tool supports consensus building. A variety of methods or combination of methods, such as group decision support rooms, AHP, interviews, surveys or voting is used depending on the application. In the TMD COEA the AHP was utilized to make pair wise comparisons of the requirements based on the documented definitions. A facilitator manages the process and captures the "Why" each time a comparison is made. This is a very important step as it gets at the rationale of the decision and aids in the understanding of the requirements and their relative priorities. This data is maintained in the framework. After all the participants have completed the comparison, the data is integrated and analyzed to identify disagreements. When necessary the process is repeated, refining

definitions or reprioritizing requirements as needed.

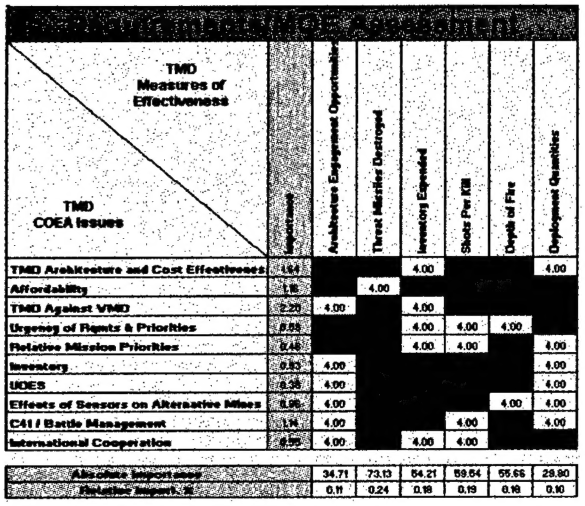

Figure 6 – Requirements/MOE Assessments

The framework supports sensitivity analysis throughout the assessment process. Figure 7 is the Requirements Prioritization Summary. This matrix permits users of the IDAPS tool to examine the individual scores of the various participants, create new priority scores, and then decide which ones get utilized in the current

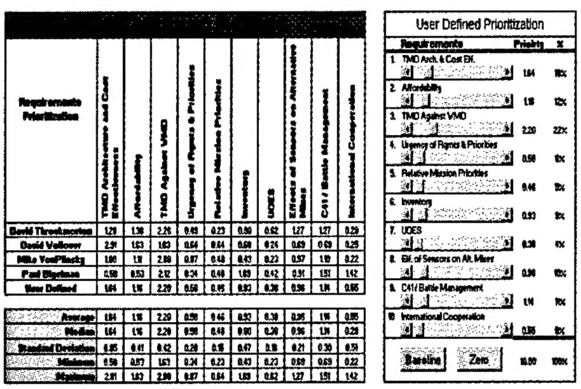

Figure 7 – Requirements Prioritization Summary

assessment. Data integrity is always preserved through access controls to the database.

Once the requirements are agreed upon and their definitions established to the lowest measurable metric, a complete inventory of MOEs is created. Criteria are subsequently created for late use in the Requirement to MOE correlation assessment. This inventory list of MOEs, the criteria, and the prioritized requirement scores provide input to the Requirements/MOE Assessment.

As noted earlier, the final product of this assessment is a weighted set of MOEs and scores that get passed forward to the Architecture Assessment. The correlation scores result as each MOE is assessed and quantified against each requirement to evaluate how well one correlates or represents the other respectively. This evaluation is accomplished for each intersection in the Requirement/MOE Assessment Matrix, Figure 6. The evaluation process can be a simple qualitative assignment, based on established and documented criteria, or a complex scheme where participants complete the evaluations individually and sensitivities analysis is used to assess the results much like that used for the requirements prioritization. Finally the correlation results are combined with the requirement priorities and summed. The result of this calculation is the Absolute Importance for each MOE. The Relative Importance (percent of 100%) is also computed and passes forward to the Architecture Assessment.

Architecture Assessment

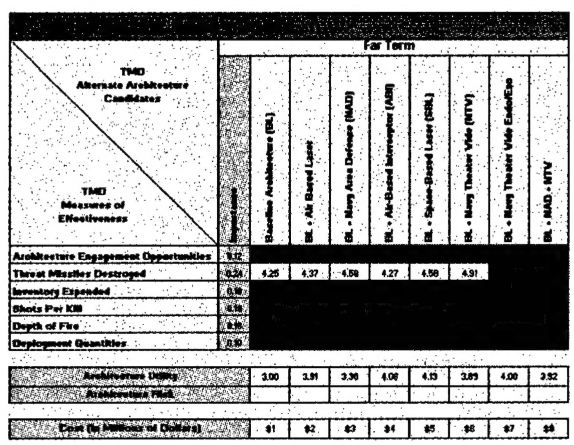

Figure 8 –Architecture Assessment

Figure 8 is the Architecture Assessment matrix. The results from the assessments are integrated

and subsequently influence the values reflected on this matrix.

The left side of the matrix contains the prioritized MOEs and scores from the Requirement/MOE Assessment matrix. The weighted MOE scores are dynamically linked so updates made anywhere in the assessment process are brought forward automatically. The various architectures being assessed are presented across the top.

A typical implementation of IDAPS usually involves designing substructures of supporting information for the architectures. These substructures may be architecture synthesis matrices that correlate systems and architectures and system performance parameter notebooks. For the TMD COEA Study this information was unavailable.

The body of this assessment (the intersections) contains architecture utility scores that are evaluated and rolled forward from raw analysis data based upon Initial Conditions set forth in the study, Measures of Effectiveness, and Architectures. The framework provides easy navigation to this data.

The data assessment begins with quantitative assessments or qualitative analysis data from models like EADSIMs or CAPS. Where possible, electronic interfaces are designed to facilitate data transfer. This process allows the IDAPS framework to maintain a configuration controlled version of the data and reduced errors from manual data input.

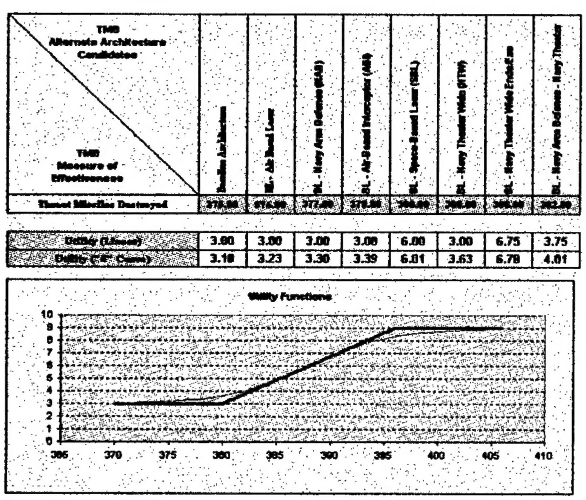

Figure 9 – Data Assessment Matrix

The Data Assessment Matrix, shown in Figure 9, is where the "Rubber Hits the Road" in the Architecture Assessment. Here qualitative analysis data is assessed based upon Key Performance Parameters (KPP) established in the CAPSTONE Requirements Document (CRD) and converted to a Quality Function Deployment (QFD) Utility score. This conversion is necessary because it transforms disparate data across a wide variety of parameters and ranges to a common scale and quality ranking.

The QFD Utility score is a measurement of goodness and represents the architecture's performance against established KPPs in the CRD or other criteria established by the user community.

Conversion Criteria is established and coordinated with the user community for each MOE and Initial Condition. Several functions are possible for converting analysis data to a QFD score. Two functions represented in Figure 9 are the linear conversion and the utility curve conversion. Other functions like a step function may also be utilized. The key is to coordinate these conversion functions with the user community and get consensus on the goodness values they produce.

The TMD COEA IDAPS Framework provides a series of Sensitivity Analysis Capabilities from the Data Assessment Matrix. One such sensitivity is the option to adjust the Threshold or Objective values and see the effect of the new values on the overall architecture utility and CAIV profiles. Possibly a slight reduction in requirements could yield major cost savings. This capability permits the user to assess such questions. Additional sensitivities provide the option of manipulating the conversion function. They are adjustment of the scaling factor (must stay between 1 and 10) and the selection of a linear function or a utility function for the conversion. This capability is supports initial assessments and the development of a user approved conversions.

An additional feature supported by this framework is the use of call outs or notes that flag unusual or diffe
example where this m
comparison of data a
have only partially analy

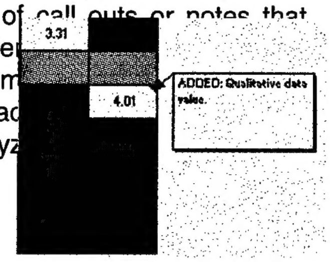

Figure 10 – Call out

was not analyzed or missing. The framework supports a qualitative assessment of the perceived architecture utility. This qualitative assessment can be combined with the quantitative assessments to complete the Architecture Assessment.

Summary Matrices, not shown here, are used to collect and integrate the utility scores across all the initial condition sets by architectures for each MOE. Separate sheets provide for Near and Far Term assessments. The Total Utility Scores appear at the bottom of each Summary Matrix. These scores are the utility values summed by architectures across the initial conditions. These scores are then averaged and passed forward to the Architecture Assessment.

In the TMD COEA Architecture Assessment, separate Summary Matrix exists for each MOE and EPOCH combination. This realization provides insight into the vast trade space considered in the TMD COEA Study. Consider the full range of options – 144 Initial Condition Permutation, 8 Architectures, 6 Measures of Effectiveness. This yields 6912 possible analysis points to be individually assessed. ***The broadly scoped TAMD Acquisition Roadmap Study demands a larger trade space consideration.***

Data pedigree is maintained throughout the assessment proves and is obtained through user friendly navigational controls.

In conclusion, the Architecture Assessment represents the combined assessments for all the architectures, across all the MOE, and across all the initial conditions – a vast trade space of assessments. These values culminate on the Architecture Assessment matrix and are individually multiplies with the importance values computed for the MOEs. The Products are then summed for the architectures to product the Architecture Utility Score.

Though not applied to the TMD COEA Study, the IDAPS Framework also supports Risk and Cost Assessments. Risk values can be assessed in much the same way described above for systems and combined at the architectures level. Cost values are integrated to develop CAIV Profiles and support the Acquisition Roadmap.

Assessment Results and Post Processing

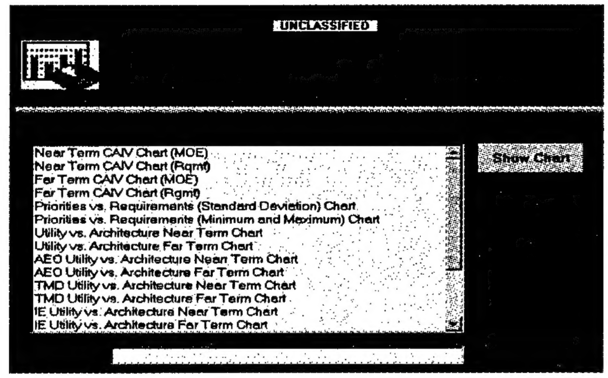

Figure 11 – Assessment Results

The final product of the IDAPS Framework is the assessment results. Figure 11 identified numerous charts and graphs that present the assessment results from a variety of perspectives. There are four CAIV profiles - Near and Far Term profiles that support requirement sensitivity assessments and the same for MOE assessments. An example of these CAIV Profiles supporting Requirements sensitivities is shown in Figure 12. The chart contains slider bars that permit the user to adjust the importance of each requirement. As the adjustments are made, the scores are recomputed and rolled up from the appropriate place in the Architecture Assessment and the impacts are realized immediately.

The final Sensitivity provided in the TMD COEA IDAPS takes a snap shot of the Architecture Assessment Matrix and subsequently supports the creation of additional utility charts and graphs. The added feature in this module is the save feature. This module allows the user to save off different "cases" as various changes are made throughout the assessment and then plot comparisons between the "cases".

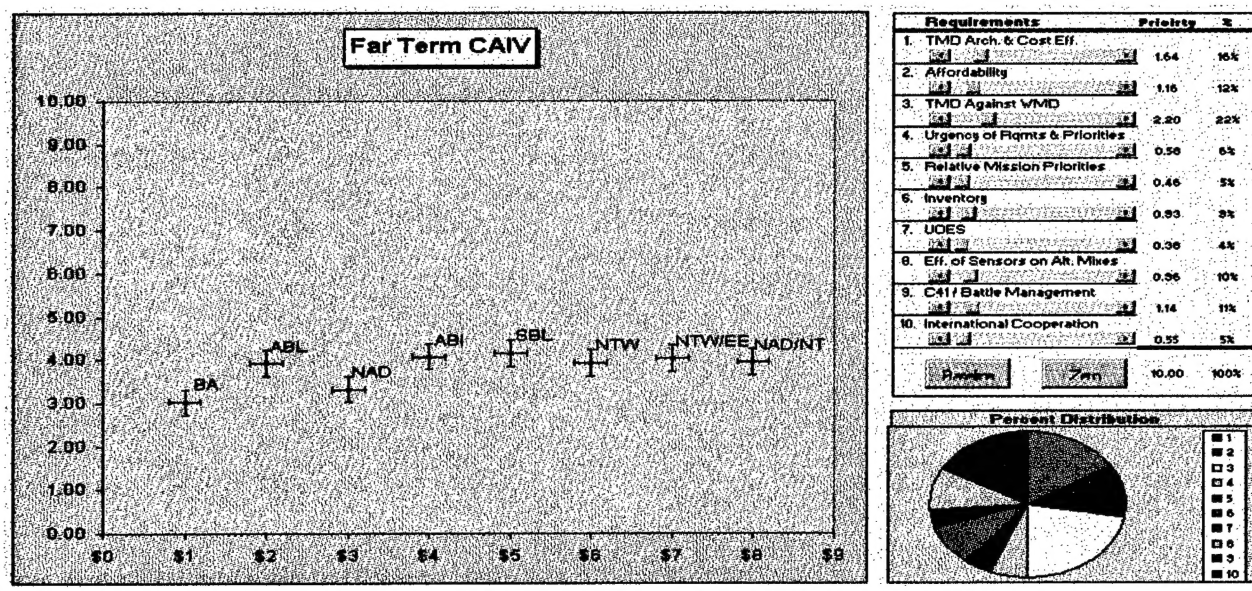

Figure 12 – Far Term CAIV with Requirements Sensitivities

Benefits of the IDAPS Process

This COTS-Based IT Automation Tool Brings a Host of GUI-Driven Features For Data Access, Integration, Manipulation, Visualization, and Control while the IDAPS Engineering Process and Framework provides the customer with a:

- Comprehensive Analytical Environment for Assimilating the Growing Complexity of Analytical Data
- Requirements Analyses and Prioritization Methodology that Establishes Warfighter Needs and Traces These Needs Through CAIV Results
- Consistent Standard for Establishing and Weighting MOEs According to How Strongly They Correlate to Requirements
- Architecture Utility Scores based on Established Performance Parameters that Support CAIV Sensitivity Analyses and Provide Decision Makers With Best Options at a Given Cost
- Framework that Supports the Incorporation of Cost, Schedule and Technical Risk Into the Comparative Architecture Assessment Process
- Framework that Supports the Technology Investment Strategy Determination by Assessing the Impacts of Technology on Architecture Alternatives and CAIV Results

Conclusions

Frontier Technology, Inc., a small business in both the DoD and commercial marketplaces, specializes in combining engineering and analyses expertise with information technology solutions to address a range of customer needs. Our Integrated Desktop Analysis and Planning System (IDAPS) provides comparative architecture / system / technology assessments based on CAIV profiles developed from input cost data and overall "utility" that is solidly based upon and is overtly traceable to the Warfighter's requirements.

The IDAPS Tool set, a centerpiece of FTI's product line, is a suite of software tools in an integrated desktop environment for advanced automated decision analysis and planning. Key IDAPS features include:

1) A flexible data/knowledge base manager;
2) A graphical user interface to access and execute PC-based "Quick-Turn" models, to accept results from legacy models using Response Surface techniques, and to directly access any other pertinent archived information;
3) A wide assortment of relevant effectiveness, risk, cost estimation models/tools;

4) An embedded "operations research" modules, such as linear programming and QFD, to provide the overall decision framework context for the analysis;
5) An automated report/briefing generation capability;
6) An on-line help facility.

The framework establishes a chain-of-assessment across the entire trade space: complete forward and backward traceability from prioritized requirements through MOEs to comparative architecture assessments to Acquisition Roadmap considerations of impacts of architecture changes off of the baseline. Inherent to this is facilitating coordinated consideration of essential ground rules and assumptions, initial conditions, institutional influences, and other factors that qualify the analytical results from the decision-maker's perspective. Another key benefit of the tool is its ability to provide the analyst/decision maker an audit trail of the information used in the analysis and an automated archival of the range of results and conditions of the study.

In summary, as a quick-turn analytical tool, IDAPS provides a means to quickly identify, which, of potentially hundreds of concepts, warrants further study and possible implementation. The tool suite allows the user to reach into on-line or off-line databases and use the data in a user-friendly manner. Additionally, IDAPS ties the analysis results and cost information back to the decision making process via CAIV.

IDAPS has a flexible open architecture that can be easily modified or extended to meet specific user needs. Customer investments totaling over $6 M in IDAPS over the last 5 years provide a sound development base for IDAPS tailoring. Since many IDAPS modules can be applied to new applications, our customers can gain high leverage for their invested resources, in both time and personnel costs.